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13. ABSTRACT (Maximum 200 words)

This Final Report covers the research on two projects: self-assembly by controlled precipitation and thin lateral oxide barrier fabrication. We obtained several important experimental findings that demonstrate the practicality of these techniques for high-throughput nanostructure fabrication. Three of our findings demonstrated experimentally the capabilities of the controlled precipitation process and the fourth increased understanding of the mechanism. We also characterized and compared oxides produced by two thin lateral oxide barrier fabrication processes.

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FINAL REPORT

Patterned Self-Assembly in
Non-stoichiometric Semiconductors

Contract F49620-97-1-0444

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For the period

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Department of the Air Force

AASERT Final Report

Status. This final report covers the research on two projects: self-assembly by controlled precipitation, and thin lateral oxide barrier fabrication. We obtained several important experimental findings that demonstrate the practicality of these techniques for high-throughput nanostructure fabrication.

Accomplishments and New Findings. Three of our findings demonstrated experimentally the capabilities of the controlled precipitation process, and the fourth increased understanding of the mechanism. We also characterized and compared oxides produced by two thin lateral oxide barrier fabrication processes.

Controlled Precipitation

Our first new finding was the demonstration of size uniformity for small arsenic precipitates in non-stoichiometric GaAs-based compounds. High temperature (850 C) and short time (30 seconds) anneals result in large (~14 nm) particles. Lower temperatures (600 C) result in smaller particles (~4 nm), but wider distributions in particle size. Increasing the anneal time by a factor of 1000, however, resulted in a narrower and more symmetric particle size distribution, as shown in the histograms in Figure 1. This uniform distribution of small particles is an important requirement for the fabrication of nanoelectronic devices.

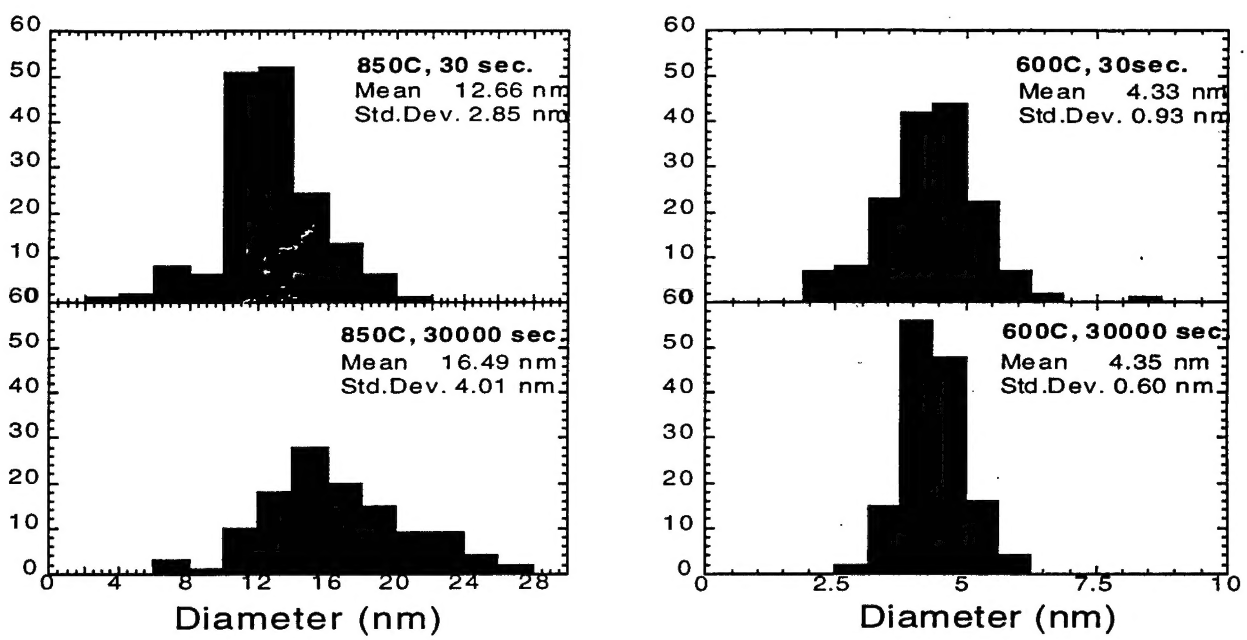

Figure 1. Histograms showing the time dependence of the particle size distribution during annealing for large particles (left) and small particles (right). The size distribution widens for large particles, but narrows for small particles.

Our second new finding was the establishment of arsenic precipitate position in the growth (vertical) direction by compositional control. We sandwiched a thin GaAs layer between

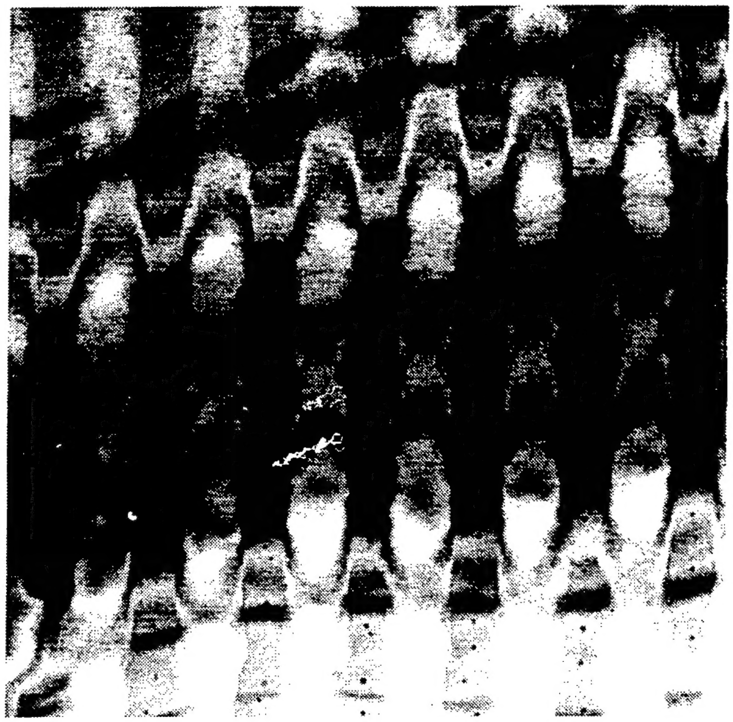

Figure 3. Plan view TEM micrograph showing the formation of a line of particles centered beneath each stressor (gray vertical bands) with completely clear fields in the spaces (light vertical bands) been the stressors. The stressors are about 0.1 microns wide.

Our fourth finding relates to the mechanism of the strain patterning effect. Our experimental results on the strain patterning for different anneal times show that the distribution of the particles in the early stage of the precipitation process is uniform with no spatial dependence in particle size or position. We conclude that the strain patterning occurs through a coarsening process, where certain particles grow while others shrink during annealing (similar to Ostwald ripening), rather than through the effect of strain on the nucleation barrier. This is an important step toward gaining an understanding of the detailed mechanism of this process to allow its optimization.

Lateral Oxide Barrier Fabrication

We investigated two methods for fabricating lateral oxide barriers in thin films: scanning probe microscope (SPM) oxidation and current-induced local oxidation (CILO). We looked into the effects of oxidation voltage, tip translation speed, and ambient humidity on the width and thickness of the oxide lines. Thin oxide barriers were achieved with low oxidation voltages, high translation speeds, and low humidity. Below certain critical voltages, or above certain speeds, oxidation would not occur, however. We also examined several candidate materials for both the SPM tip coating and the thin film.

We performed experiments with CILO, creating current constrictions formed by both SPM oxidation and electron beam lithography. We investigated the role of oxidation bias and current density on the width and thickness of the oxide barriers.

Using both methods, we produced Ti oxide barriers less than 100 nm wide in a 3 nm-thick Ti film and measured the barrier height. AFM micrographs of the barriers and their

Publications.
C.-Y. Hung, J. S. Harris, Jr., A. F. Marshall, and R. A. Kiehl, "Arsenic Precipitation in GaAs for Single-Electron Tunneling Applications," 24th Intl. Symp. Compound Semiconductors, San Diego, CA, Sept. 8-11, 1997.

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New Inventions. None.

Honors/Awards. Richard A. Kiehl was elected Fellow, Institute of Electrical and Electronic Engineers, January, 1998.